NOAA RESEARCH • ESRL • PHYSICAL SCIENCES DIVISION

20th Century Reanalysis

Gilbert P. Compo

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PSD's 20th Century Reanalysis v2c implementation of Ensemble Kalman Filter Algorithm

(Whitaker and Hamill 2002, Whitaker et al. 2004, Compo et al. 2006, Compo et al. 2011)

PSD algorithm makes a weighted average of pressure observations and an ensemble of GCM forecasts.

The weight **K** varies with the atmospheric flow and the observation network.

$$\text{Analysis} = (1\text{-}\mathbf{K})\ \text{Forecast} + \mathbf{K} * \text{pressure obs}$$

Using 56 member ensemble, new prescribed boundary conditions:

SODAsi.2c 18 member pentad SST and COBE-SST2 monthly sea ice (**fixes sea ice bug**) [*Giese et al. 2015*, *Hirahara et al. 2014*]

New observations: *International Surface Pressure Databank 3.2.9*, millions of new observations from Oldweather.org, ACRE, NCDC, universities, Met services.

1851-2011: T62 (~200km), 28 level NCEP GFS08ex atmosphere/land model

9 hour forecasts for 6 hour centered analysis window

- time-varying CO_2, solar and volcanic radiative forcing (Sato et al.)

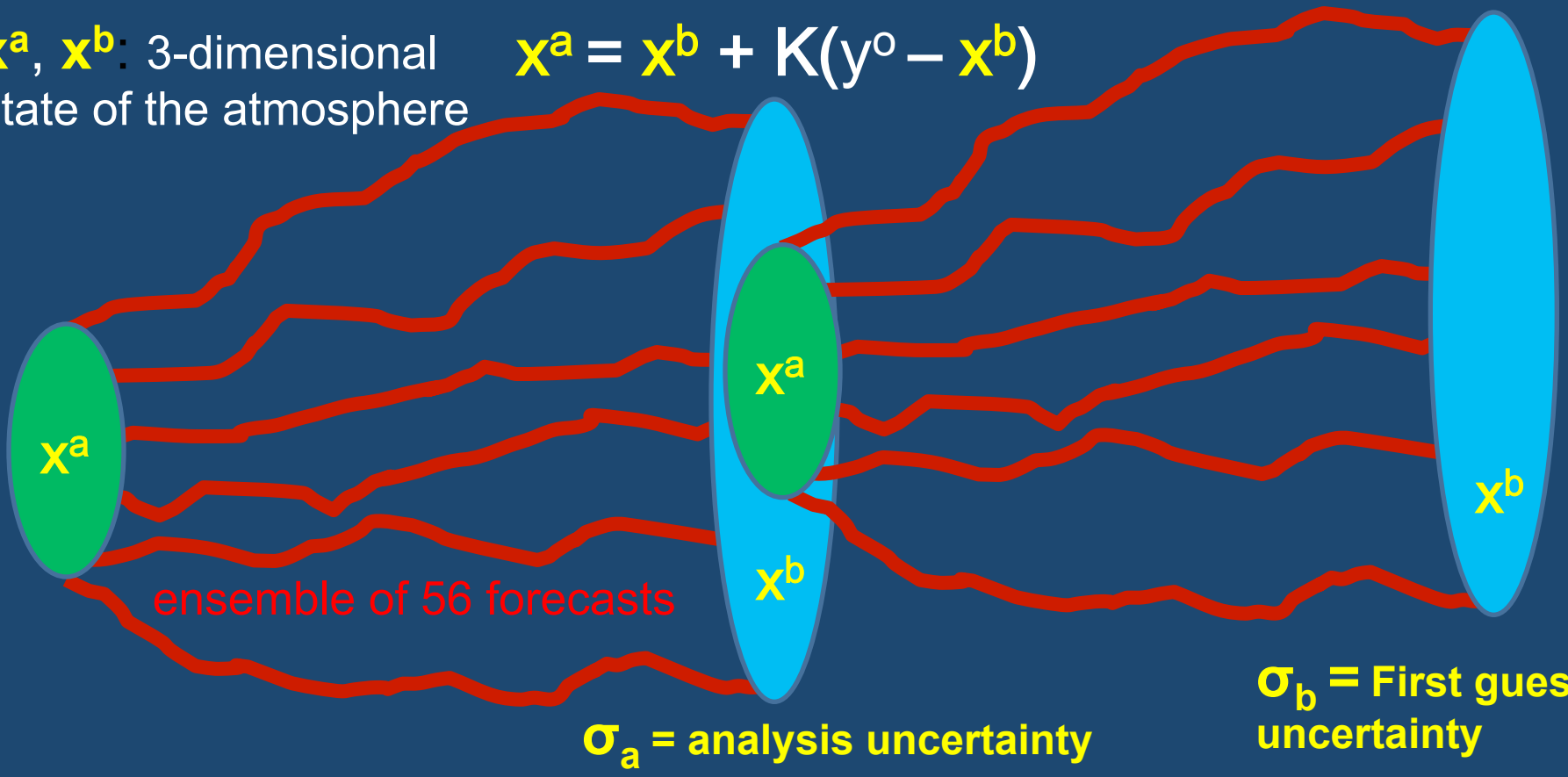
http://go.usa.gov/XTd Compo et al. 2011, doi:10.1002/qj.776

20CR Ensemble Data Assimilation (Compo et al. 2011)

20CR analysis x^a is a weighted average of the first guess x^b and pressure observation y^o. Each observation is assimilated serially.

x^a, x^b: 3-dimensional state of the atmosphere

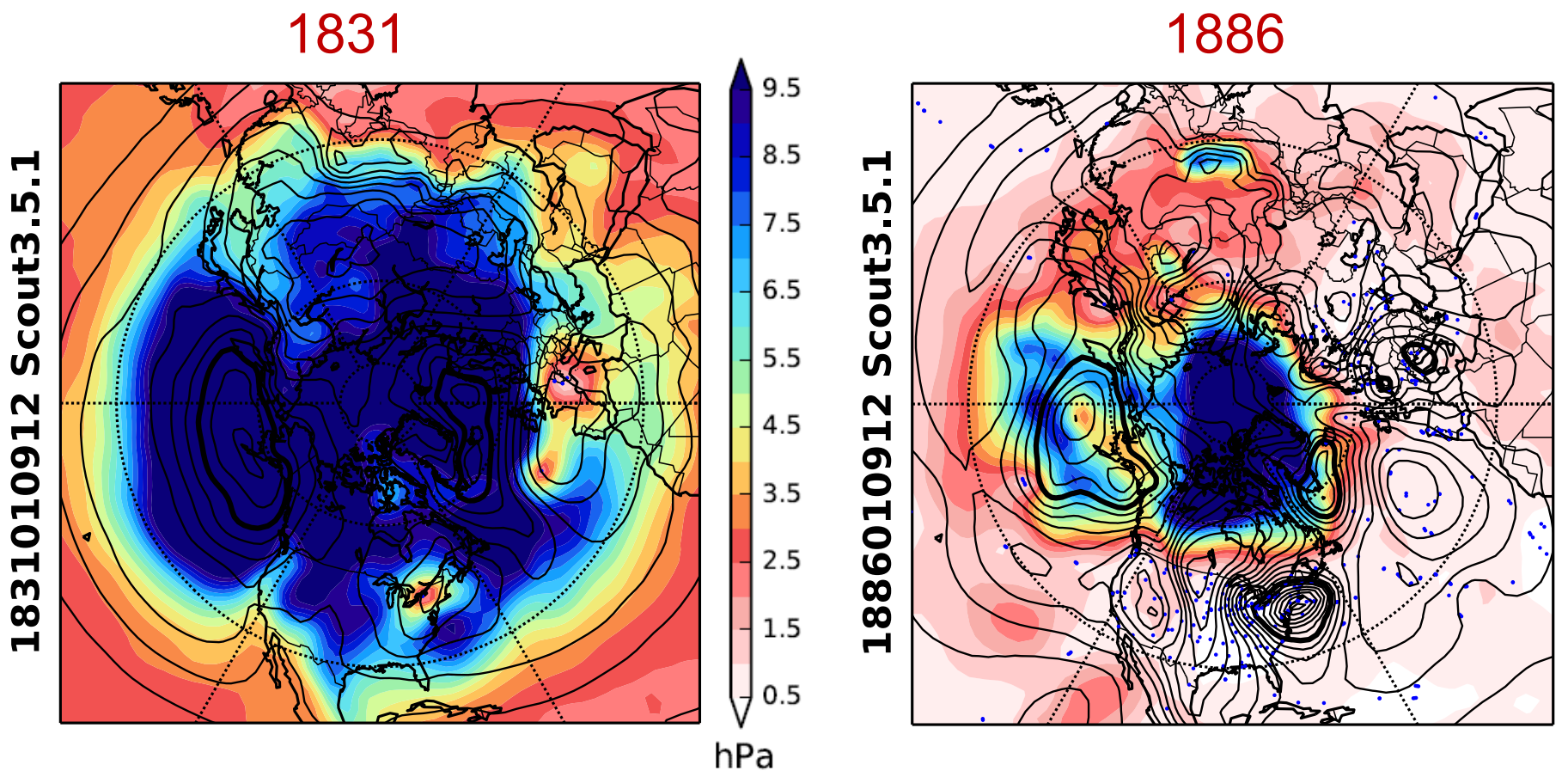
$$x^a = x^b + K(y^o - x^b)$$



the weight **K** varies with the atmospheric flow and the observation network

analysis time (0Z) **analysis time (6Z)** **analysis time (12Z)**

20CRv2c Analyses of Sea Level Pressure for selected dates in 1831 and 1886

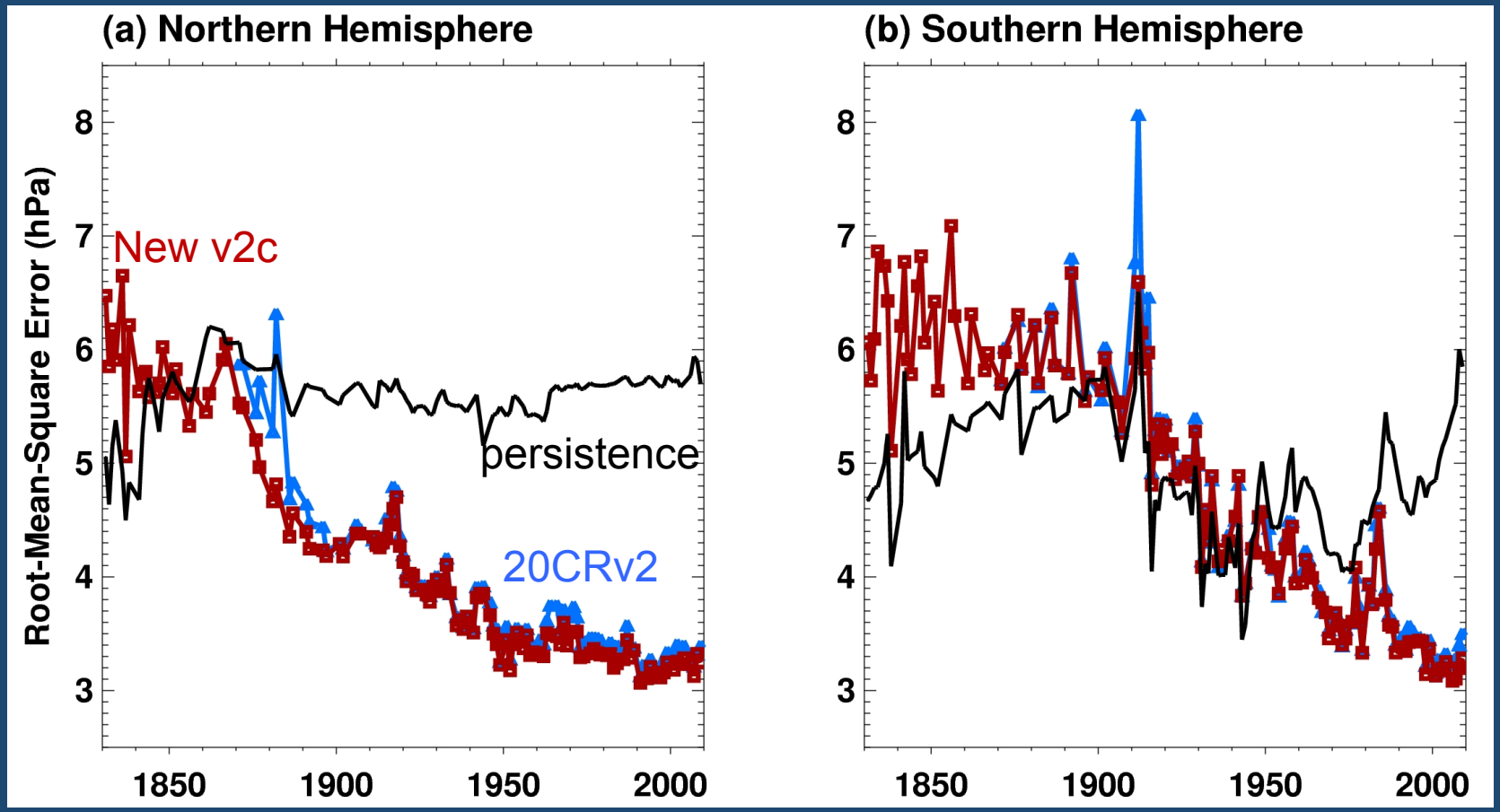


Contours-ensemble mean (ci: 4 hPa, 1000 hPa thickened)

Shading- blue: more uncertain, white: more certain

Analysis system responds to the observations and the flow, providing quantitative uncertainty for every variable at each analysis time.

Root Mean Square difference of Surface and Sea Level Pressure Observations and 24 hour Forecasts from 20CRv2 and v2c (*Jan-Dec*)



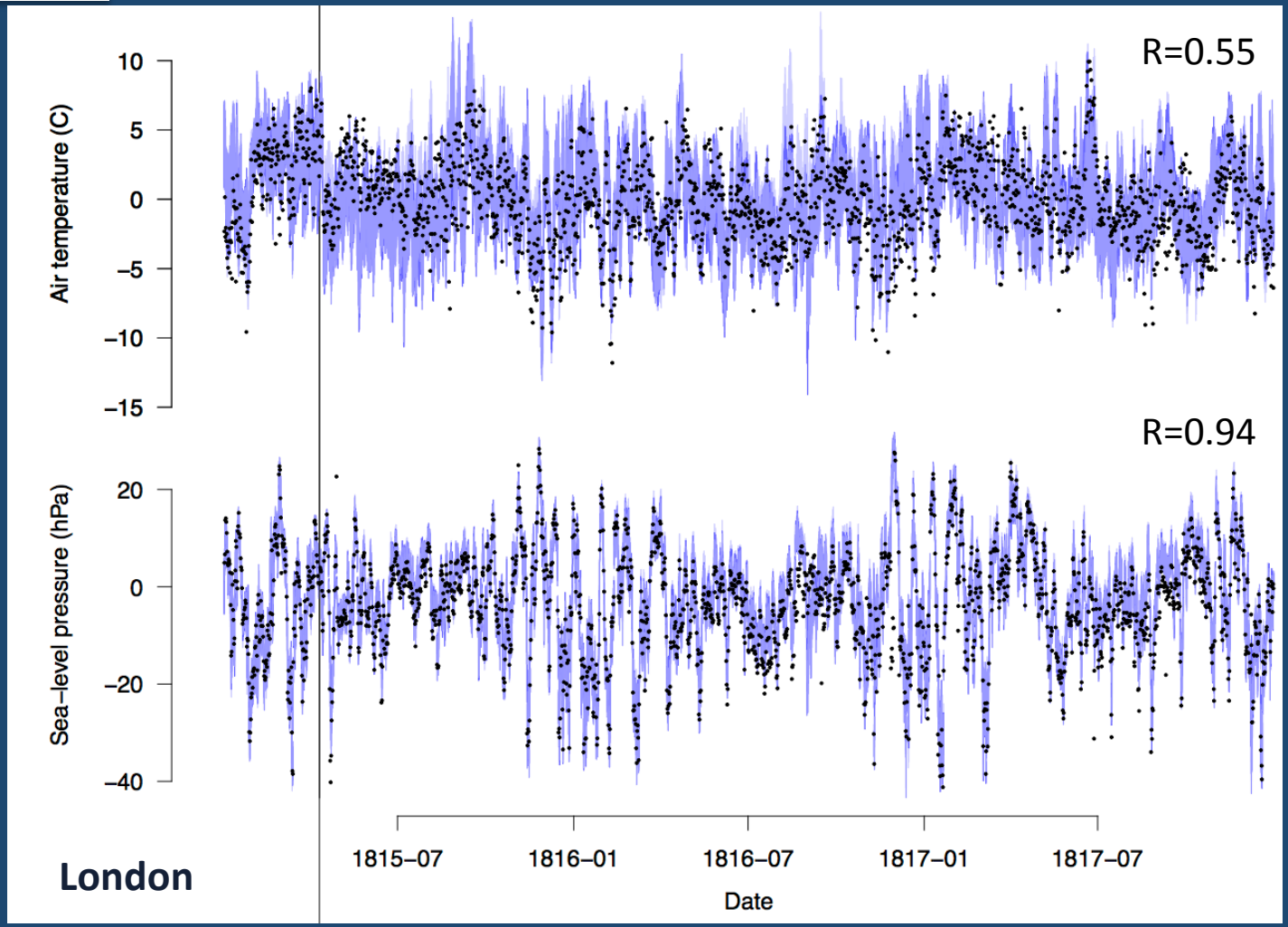
Northern Hemisphere 24 hr forecasts beat persistence even in 1850s. Southern Hemisphere has an analysis that produces forecasts comparable to persistence starting in 1900s. New v2c is an improvement.

Reconstructing the effects of Tambora 1815 and the Year Without a Summer of 1816

Comparison of anomalies from

Black dots: subdaily independent Air T and assimilated SLP from London

Purple swaths: 20CR-1815 ensemble range (1815 to 1817)



~4 other N. American and ~10 European Station, and ~10 Ship Obs assimilated each day.

2-4 times more possible.

In regions such as Europe, 20CR-1815 compares well, showing skillful weather variability from the pressure observations. 1816 doesn't appear particularly anomalous in either dataset.

(Compo, Brohan, Whitaker, Broennimann, Brugnara, Allan, Sardeshmukh 2015)

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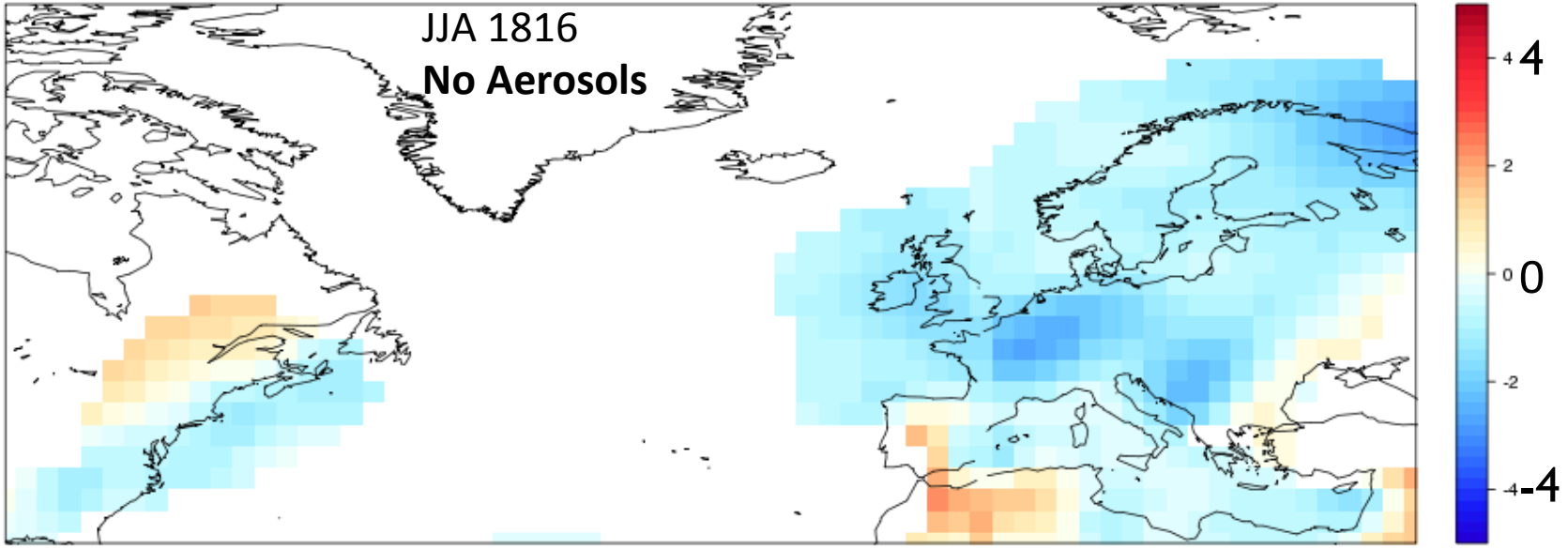
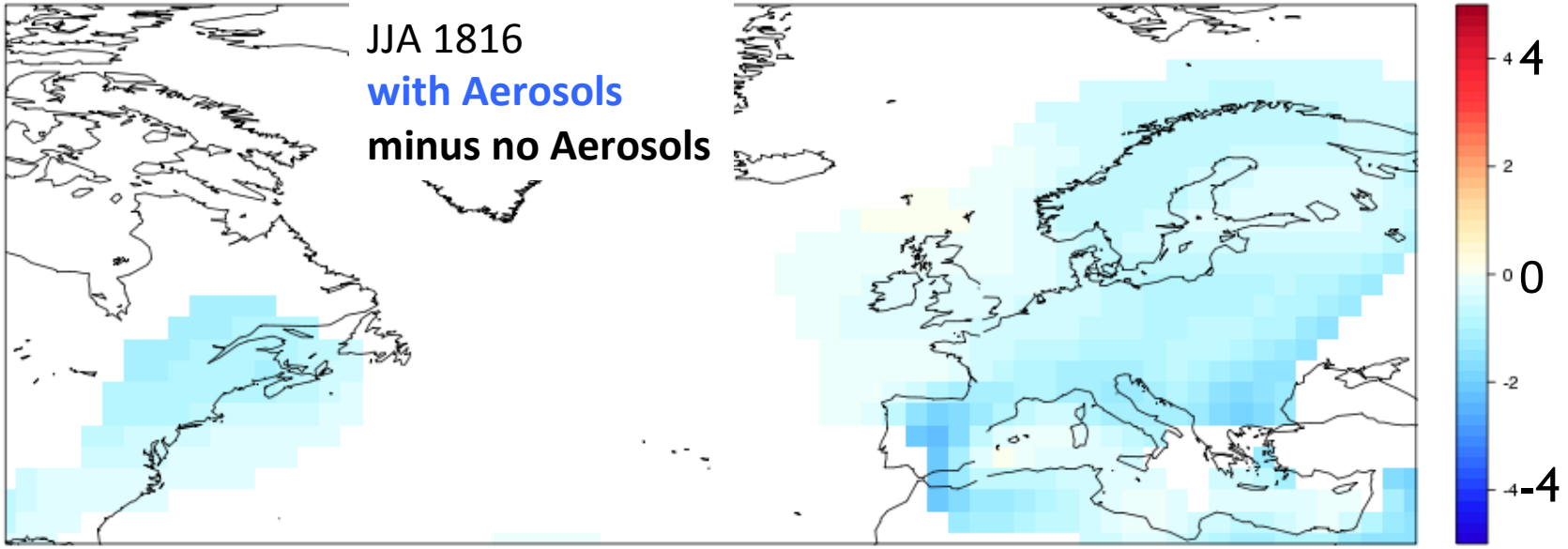


20CR JJA 1816 2m temperature anomaly (C) - **No Aerosols**



Additional cooling effect of adding Crowley aerosols is moderate but detectable.

Summary and Conclusions

- PSD has generated first 20CRv2 1871-2012 and now "2c" 1851-2011 ensemble reanalysis.
- Used in many studies of climate, weather and water variability and extremes (more than 500 citations since 2011; most in PSD and CIRES).
- **Unexpected uses**: e.g., iceberg risk during the Titanic (1912), coastal storm surge risk, and Tse fly variability.
- **Coordinating** with NCEP and NCDC on a consistent suite of NOAA Climate Reanalyses using upper-air and satellite observations.
- **Future**: improved algorithm, higher resolution model, longer span (200 years could be possible! Quality would depend on region).

Thank you to organizations contributing observations to ISPD:

All Russia Research Institute of Hydrometeorological Information WDC
Atmospheric Circulation Reconstructions over the Earth (ACRE)
Australian Bureau of Meteorology
Australian Meteorological Association, Todd Project Team
British Antarctic Survey
Canadian Volunteer Data Rescue Project
Cook Islands Met Service
Danish Meteorological Institute
Deutscher Wetterdienst
EMULATE
Environment Canada
ERA-CLIM
ETH-Zurich
European Reanalysis and Obs for Monitoring
GCOS AOPC/OOPC WG on Surface Pressure
GCOS/WCRP WG on Obs Data Sets
Hong Kong Observatory
Icelandic Meteorological Office
IBTrACS
ICOADS
IEDRO
JAMSTEC
Japan Meteorological Agency
Jersey Met Dept.
Lamont-Doherty Earth Observatory
KNMI
MeteoFrance
MeteoFrance – Division of Climate
Meteorological and Hydrological Service, Croatia
National Center for Atmospheric Research
Nicolaus Copernicus University
Niue Met Service
NIWA
NOAA Climate Database Modernization Program
NOAA Earth System Research Laboratory
NOAA National Climatic Data Center
NOAA National Centers for Environmental Prediction
NOAA Northeast Regional Climate Center at Cornell U.
NOAA Midwest Regional Climate Center at UIUC
NOAA Pacific Marine Environmental Laboratory
Norwegian Meteorological Institute
Oldweather.org
Ohio State U. – Byrd Polar Research Center
Portuguese Meteorological Institute (IM)
Proudman Oceanographic Laboratory
SIGN - Signatures of environmental change in the observations of the Geophysical Institutes
South African Weather Service
UK Met Office Hadley Centre
U. of Bern, Switzerland
U. of Colorado-CIRES/Climate Diagnostics Center
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